

46. (New) A method of adjusting a fuel injector for a fuel injection system of an internal combustion engine, in particular for direct injection of fuel into a combustion chamber of the engine, the fuel injector including an actuator, a valve needle to be acted upon by a restoring spring in a closing direction and being mechanically linked to the actuator to actuate a valve closing body which, together with a valve seat face, forms a sealing seat, and a sleeve to pre-stress the restoring spring, an adjusting body being mounted so as to be adjustable in the sleeve, so that a fuel flow rate of the fuel flowing through the fuel injector per unit of time depends on a position of the adjusting body in the sleeve, the method comprising:

measuring a static actual flow through the fuel injector;

comparing a measured static actual flow rate with a static setpoint flow rate; and

adjusting the adjusting body in the sleeve until the actual flow rate corresponds to the static setpoint flow rate.

47. (New) The method of claim 46, wherein the adjusting body is adjusted in the sleeve by turning it using a first adjusting tool.

48. (New) The method of claim 46, wherein the adjusting body is adjusted in the sleeve by pressing it in using an adjusting bolt.

49. (New) The method of claim 46, wherein an adjustment of the static flow rate by the adjusting body and another adjustment of a dynamic flow rate by axial displacement of the sleeve are performed independently of one another.

50. (New) The method of claim 49, wherein the axial displacement of the sleeve is performed by turning it using a second adjusting tool.

Remarks

This Preliminary Amendment cancels without prejudice original claims 1 to 25 in the underlying PCT Application No. PCT/DE01/02705, and adds without prejudice new claims 26 to 50. The new claims conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

In accordance with 37 C.F.R. § 1.121(b)(3), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to U.S. Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. § 1.121(b)(3)(iii) and § 1.125(b)(2), a Marked Up Version Of The Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. In the Marked Up Version, underlining indicates added text and bracketing indicated deleted text. Approval and entry of the Substitute Specification (including Abstract) is respectfully requested.

The underlying PCT Application No. PCT/DE01/02705 includes an International Search Report, dated January 22, 2002. The Search Report includes a list of documents that were uncovered in the underlying PCT Application. A copy of the Search Report accompanies this Preliminary Amendment

Applicant asserts that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

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FUEL INJECTOR AND METHOD FOR ITS ADJUSTMENT

[Background Information

] FIELD OF THE INVENTION

The present invention is [based on] related to a fuel injector
[according to the preamble of Claim 1] and a method of
5 adjusting a fuel injector [according to the preamble of Claim
11].

BACKGROUND INFORMATION

German Published Patent Application No. 40 23 828 [A1
10 describes] discusses a fuel injector and a method of adjusting
a fuel injector. To adjust the amount of fuel to be delivered
during the opening and closing operation of the
electromagnetically operable fuel injector, a magnetically
conductive material, e.g., in the form of a powder which
15 alters the magnetic properties of the internal pole is
introduced into a blind hole, and thus the magnetic force is
varied until the actual measured flow rate of the medium
corresponds to the predetermined setpoint flow rate.

20 Similarly, German Published Patent Application No.
40 23 826 [A1 describes] discusses the insertion of an
equalizing bolt into a blind hole of an internal pole [having]
including a recess on its periphery, inserting it to the
extent that the actual measured amount corresponds to the
25 predetermined setpoint amount, and thus varying the magnetic
force until this is achieved.

German Patent Published Application No. 195 16 513 [A1] also
[describes] discusses a method of adjusting the dynamic flow

rate of a fuel injector. In this case, an adjusting element situated close to the magnetic coil outside the flow path of the medium is adjusted. In doing so, the size of the magnetic flux in the magnetic circuit, and thus the magnetic force, changes, so it is possible to influence and adjust the flow rate. The adjustment may be performed with when the fuel injector is either wet or dry.

German Patent Published Application No. 42 11 723 [A1 describes] discusses a fuel injector and a method of adjusting the dynamic flow rate of the medium of a fuel injector, in which an adjusting sleeve [having] including a longitudinal slot is pressed into a longitudinal bore in a connection piece up to a predetermined depth, the dynamic actual flow rate of medium of the injector is measured and compared with a setpoint flow rate of medium, and the pressed-in adjusting sleeve which is under a tension acting radially is advanced until the actual measured flow rate of the medium matches the predetermined setpoint flow rate of the medium.

In German Published Patent Application No. 44 31 128 [A1], to adjust the dynamic flow rate of medium of a fuel injector, the valve housing undergoes deformation due to the action of a deformation tool on the outer perimeter of the valve housing. This changes the size of the residual air gap between the core and the armature, and thus the magnetic force, so that it is possible to influence and adjust the flow rate of medium.

One disadvantage of the group of methods which influence the magnetic flux in the magnetic circuit is [in particular] the great expense with regard to manufacturing costs, because the required static flow tolerances must be guaranteed, although this is difficult to implement. In particular, measurements of magnetic fields are complicated to perform and usually require cost-intensive methods and a test field.

It is believed that a [One] disadvantage of the group of mechanical adjustment methods is [in particular] the high degree of inaccuracy to which these methods [are] may be subject. Furthermore, the opening and closing times of a fuel injector may be shortened only at the expense of electric power, so that the electric load on the components is increased, and the controllers are under greater stress.

In particular, the method [known from] referred to in German Published Patent Application No. 44 31 128 [A1], where the residual air gap between the core and the armature is varied by deformation of the valve housing, permits only a very inaccurate correction of the flow rate because shear stresses in the nozzle body may have a negative effect on the direction and size of the deforming force. Therefore, a high manufacturing precision is necessary for all parts.

[Advantages of the Invention

] SUMMARY OF THE INVENTION

The exemplary fuel injector according to the present invention [having the characterizing features of Claim 1] and the exemplary method according to the present invention for adjusting a fuel injector, [having the features of Claim 21 have the advantage over the related art that] due to the introduction of an adjusting body into a sleeve which [is] may be pressed into the valve body, may allow the flow rate to be monitored and adjusted in [it is possible to monitor and adjust the flow rate by] a [simple] mechanical [way] manner.

[Advantageous refinements of the fuel injector characterized in Claim 1 and the method characterized in Claim 21 are possible through the measures characterized in the subclaims.
]

The [It is advantageous in particular that it is possible to adjust] flow rate may be adjusted after the fuel injector has already been installed. The adjusting body [is] may be

accessible from the outside on its end facing the fuel feed and may be displaced as desired in the sleeve and pushed into the aperture plate by an adjustment bolt after measurement of the actual amount.

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The [design] configuration of the sleeve [having] including a thread which cooperates with a thread provided on the adjusting body [is advantageous, so that it is possible to secure] may allow the adjusting body to be [in the] securely set in position very well. In addition, [it is possible to unscrew] the adjusting body may be unscrewed from the sleeve again to replace it[, for example].

The aperture plate, whose cross section may be increased or reduced by introducing the adjusting body, may also be used in mass-produced fuel injectors. The adjustment of the adjusting body in the sleeve and the manufacture of the adjusting body, the sleeve and the aperture plate may be accomplished [by simple means] in a simple manner in terms of the manufacturing technology.

The [It is also advantageous that it is possible to adjust the] static and dynamic flow rates may be adjusted separately, so that the preset flow rates need not be altered by further adjustments.

Other [The fact that other] adjustment features of the fuel injector [are] may not be affected by the adjustment of the flow rate through the sleeve and the adjusting body [is also advantageous].

[Drawing

] Exemplary embodiments [Embodiments] of the present invention are illustrated [in simplified form] in the [drawing] diagrams and are explained in greater detail in the following

description.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a schematic sectional view through an exemplary embodiment of a fuel injector according to the related art.

Figure 2A shows a detail of a schematic section through a first exemplary embodiment of the fuel injector according to the present invention in area II in Figure 1.

Figure 3 shows a detail of a schematic section through a second exemplary embodiment of the fuel injector according to the present invention in area II in Figure 1.

Figure 4 shows a detail of a schematic section through a third exemplary embodiment of the fuel injector according to the present invention in area II in Figure 1.

Figure 5A-C show details of schematic cross sections through the interior part of the third exemplary embodiment of the fuel injector according to the present invention along line V-V in Figure 4 in various exemplary embodiments.

Figure 6A shows a detail of a schematic section through a fourth exemplary embodiment of the fuel injector according to the present invention in area II in Figure 1.

Figure 6B shows a detailed view of the interior part of the fourth exemplary embodiment of the fuel injector according to the present invention.

[Description of the Exemplary Embodiments

] DETAILED DESCRIPTION

Before describing three exemplary embodiments of a fuel injector according to the present invention in greater detail on the basis of Figures 2 through 5, a known fuel injector of

the same design as in the exemplary embodiments, except for the measures according to the present invention, will first be explained briefly with regard to its essential components on the basis of Figure 1.

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Fuel injector 1 [is designed] may be configured in the form of a fuel injector for fuel injection systems of internal combustion engines having spark ignition of a fuel-air mixture. Fuel injector 1 [is] may be suitable [in particular] for direct injection of fuel into a combustion chamber [(not shown)] of an engine.

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Fuel injector 1 [has] may include a nozzle body 2 in which a valve needle 3 [is] may be guided. Valve needle 3 [is] may be mechanically linked to a valve closing body 4 which cooperates with a valve seat face 6 situated on a valve seat body 5 to form a sealing seat. In this exemplary embodiment, fuel injector 1 [is] may be an inwardly opening fuel injector 1 [having] including an injection orifice 7. Nozzle body 2 [is] may be sealed by a seal 8 with respect to stationary pole 9 of a magnetic coil 10. Magnetic coil 10 [is] may be encapsulated in a coil housing 11 and [is] may be wound on a field spool 12 which [is] may be in contact with an internal pole 13 of magnetic coil 10. Internal pole 13 and stationary pole 9 [are] may be separated by a gap 26 and [are] may be supported on a connecting component 29. Magnetic coil 10 [is] may be energized over a line 19 by electric current supplied via an electric plug contact 17. Plug contact 17 [is] may be surrounded by a plastic sheathing 18 which may be integrally molded on internal pole 13.

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Valve needle 3 [is] may be guided in a valve needle guide 14 which [is] may be designed in the shape of a disk. A matching adjustment disk 15 [is] may be used to adjust the lift. On the other side of adjustment disk 15 there [is] may be an armature 20 which [is] may be in a friction-locked connection with

valve needle 3 via a flange 21, the valve needle being joined to flange 21 by a weld 22. A restoring spring 23 [is] may be supported on flange 21; in the present design of fuel injector 1, the restoring spring [is] may be pre-stressed by a sleeve 24. Fuel channels 30a through 30c, which carry the fuel that [is] may be supplied through a central fuel feed 16 and filtered through a filter element 25 to injection orifice 7, run in valve needle guide 14, armature 20 and on valve seat body 5. Fuel injector 1 [is] may be sealed by a seal 28 with respect to a receiving bore (not shown), e.g., in a fuel rail.

In the resting state of fuel injector 1, armature 20 [is] may be acted upon by restoring spring 23 against its direction of lift so that valve closing body 4 [is] may be held sealingly on valve seat 6. When magnetic coil 10 is energized, it creates a magnetic field which moves armature 20 in the direction of lift against the elastic force of restoring spring 23, the lift being predetermined by a working gap 27 between internal pole 12 and armature 20 in the resting position. Armature 20 also entrains flange 21, which [is] may be welded to valve needle 3, in the direction of lift. Valve closing body 4, which [is] may be mechanically linked to valve needle 3, [is] may be lifted up from the valve seat face, and fuel [is] may be injected through injection orifice 7.

When the coil current [is] may be turned off, armature 20 drops back from internal pole 13 due to the pressure of restoring spring 23 after the magnetic field has subsided sufficiently, so that flange 21, which [is] may be mechanically linked to valve needle 3, moves against the direction of lift. Valve needle 3 [is] may be thus moved in the same direction, so that valve closing body 4 [is] may be set down on valve seat face 6, and fuel injector 1 [is] may be closed.

In an excerpt of a sectional diagram, Figure 2 shows the

detail of fuel injector 1 which is labeled as II in Figure 1.

The first exemplary embodiment of fuel injector 1 according to the present invention illustrated in Figure 2 shows the inlet-side part of fuel injector 1 without filter element 25, which is present in central fuel feed 16 in Figure 1. Whereas Figure 1 shows only sleeve 24, which [is] may be needed for adjusting the dynamic fuel flow which [is] may be influenced by the opening and closing times, the exemplary embodiment illustrated in Figure 2 also has an adjusting body 40 which [is] may be inserted into sleeve 24 and [is] may be used for adjusting the static fuel flow, i.e., the flow of fuel in the opened static state. Adjusting body 40 has a cylindrical shape in the present exemplary embodiment and [is designed] may be configured with a taper in the form of a truncated cone on injection end 41. On its injection end 42, sleeve 24 [is] may be closed by an aperture plate 43. Aperture plate 43 and sleeve 24 may be designed in one piece or they may be manufactured as two different parts. In the present exemplary embodiment, sleeve 24 and aperture plate 43 form one overall part. For the sake of facilitating installation, sleeve 24 [has] may include a lateral slot 44 which extends as far as aperture plate 43.

To regulate the static fuel flow, adjusting body 40 may be displaced in sleeve 24 in the injection direction using adjustment bolt 45. Then conical injection end 41 of adjusting body 40 [is] may be pushed into aperture plate 43. The fuel flow through fuel injector 1 decreases depending on how far injection end 41 of adjusting body 40 projects into a borehole 46 in aperture plate 43.

The dynamic fuel flow [is] may be determined by the position of sleeve 24. The further sleeve 24 [is] may be pressed into a central recess 47 in fuel injector 1 by a suitable tool [(not shown here)], the greater is the pre-stress acting on

restoring spring 23 and the longer it lasts until fuel injector 1 is opened in the opening operation or the faster fuel injector 1 may be closed in the closing operation. This means that the dynamic fuel flow through fuel injector 1 decreases with an increase in the pre-stress on restoring spring 23 or with an increase in the depth of installation of sleeve 24.

If sleeve 24 is introduced into central recess 47 in a certain desired position, the static fuel flow through fuel injector 1 when the latter is open may be adjusted via adjusting body 40. To determine the proper flow rate and the correct position of adjusting body 40 in sleeve 24, first the actual flow through fuel injector 1 [is] may be measured. The actual measured value [is] may then be compared with a predetermined setpoint value of the flow rate. Then adjusting body 40 [is] may be displaced in sleeve 24 in the direction of injection by adjustment bolt 45 until the actual value matches the setpoint value. Since it is no longer possible to remove adjusting body 40 from sleeve 24, to this end fuel injector 1 must have a static flow rate which is greater than the setpoint value before adjusting the static flow rate.

When the setpoint value for the flow rate through fuel injector 1 has been reached, adjustment bolt 45 [is] may be removed and instead filter element 25 [is] may be inserted into central recess 47 of fuel injector 1, as illustrated in Figure 1.

In a detail of a sectional diagram, Figure 3 shows the detail of a second exemplary embodiment of fuel injector 1 which is labeled as II in Figure 1.

The second exemplary embodiment of fuel injector 1 according to the present invention differs from the first exemplary embodiment illustrated in Figure 2 in the design of adjusting

body 40 which may be screwed into sleeve 24. To do so, sleeve 24 [is] may be provided with an internal thread 51 and adjusting body 40 [is] may be provided with an external thread 50. Adjusting body 40 is thus no longer pressed into sleeve 24, but instead [is] may be screwed into it by using a suitable adjusting tool 52, e.g., a screwdriver. To this end, an inlet end 53 of adjusting body 40 [has] may include a tool groove 54 in which a corresponding projection 55 on adjusting tool 52 engages.

In this exemplary embodiment of fuel injector 1 according to the present invention, it is not necessary for the actual flow rate of fuel injector 1 at the beginning of the adjustment to be higher than the setpoint flow rate, because adjusting body 40 may be screwed into any desired position in sleeve 24 via external thread 50 and internal thread 51.

Figure 4 shows a third exemplary embodiment of fuel injector 1 according to the present invention in the detail labeled as II in Figure 1.

In the present exemplary embodiment, sleeve 24 does not [have] include an aperture plate 43, but instead [is designed] may be configured as a hollow cylinder [having] including a side slot 44. Adjusting body 40 [is] may be cylindrical and [has] may include an axial groove 60 on its outer periphery. Groove 60 may have various cross sections and begins on injection end 41 of adjusting body 40, continuing to inlet end 53 of adjusting body 40 as it becomes wider.

The flow rate through fuel injector 1 [is] may be adjusted by a displacement of adjusting body 40 in the direction of injection. In contrast with the exemplary embodiments in Figures 2 and 3, where the fuel flow rate through fuel injector 1 decreases with an increase in the depth to which adjusting body 40 [is] may be screwed or pressed into sleeve

24, in the present exemplary embodiment the flow rate increases with an increase in the depth of insertion of adjusting body 40.

5 When adjusting body 40 is inserted into sleeve 24 and has been pushed in to the extent that injection end 41 of adjusting body 40 and injection end 41 of sleeve 24 are flush with one another, there [is] may be only minimal fuel flow through fuel injector 1 or none at all. The further adjusting body 40 [is] may be pressed through sleeve 24 in the direction of
10 injection, the greater is the wetted cross section made available for flow through groove 60.

15 With this [This] arrangement [has the advantage that] the flow rate need not be measured repeatedly and compared with the setpoint value, but instead adjusting body 40 [is] may be pushed continuously further into sleeve 24 until the actual value of [fuel] flow through fuel injector 1 matches the setpoint value.

20 Figures 5A-5C show cross sections through injection end 41, 42 of adjusting body 40 and sleeve 24 along line V-V. In adjusting body 40, which fills up sleeve 24, groove 60 [is designed] may be configured so that fuel flows through it in
25 the direction of the valve seat.

Groove 60 may have various cross sections. In the first exemplary embodiment, which is illustrated in Figure 5A, groove 60 is U-shaped, while the exemplary embodiment
30 illustrated in Figure 5B [has] includes a C-shaped groove 60.

The exemplary embodiment illustrated in Figure 5C, which [has] includes a flattened planar area 60 instead of groove 60, [is especially] may be simple to manufacture. Adjusting body 40
35 thus assumes the shape of a notched cylinder.

Figure 6A shows a fourth exemplary embodiment of fuel injector 1 according to the present invention. In contrast with preceding exemplary embodiments, sleeve 24 [has] may include an external thread 57 which cooperates with an internal thread 58 of central recess 47 of fuel injector 1. The position of sleeve 24 in central recess 47 of fuel injector 1 may thus be adjusted by turning it by using a suitable adjusting tool 56. The inlet end of sleeve 24 [has] may include a two-step recess 59, the diameter of which tapers in two steps 61 and 62 in the direction of the fuel flow.

In the direction of injection, sleeve 24 [is] may be supported on an intermediate sleeve 31 which [is] may be clamped between sleeve 24 and restoring spring 23. This results in no rotational force being applied to restoring spring 23 when screwing in sleeve 24, thus preventing metal shavings from being removed and also preventing the resulting contamination of fuel injector 1.

The dynamic fuel flow [is] may be defined by the position of sleeve 24, as already explained above. The further sleeve 24 [is] may be screwed into central recess 47 of fuel injector 1 using adjusting tool 56, which may be a hexagon socket wrench, for example, the greater [is] may be the pre-stress acting upon restoring spring 23, and the longer it takes for fuel injector 1 to be opened in the opening operation and the more rapidly fuel injector 1 may be closed in the closing operation. This means that the dynamic fuel flow through fuel injector 1 decreases with an increase in the pre-stress of restoring spring 23 and with an increase in the depth of installation of sleeve 24. Tool 56 then engages in recess 59 in sleeve 24 at the first step 61. The position of adjusting body 40 in sleeve 24 is not affected by screwing in sleeve 24 using adjusting tool 52.

When sleeve 24 is brought into a certain desired position in

central recess 47, the static fuel flow which flows through fuel injector 1 when the latter is opened may be adjusted via adjusting body 40. In the present exemplary embodiment this second adjustment step is identical to the [procedure] method illustrated in Figure 4. Only stepped recess 59 in sleeve 24 is different, because adjusting body 40 [is] may be displaced by tool 45, which has a smaller diameter than adjusting tool 56. Adjusting tool 45 thus acts on second step 62, without influencing the adjustment of sleeve 24 in recess 47 of fuel injector 1.

Sleeve 24 [having] including external thread 57 may be combined with any desired adjusting body 40, in particular with adjusting bodies 40 described in conjunction with Figures 2 and 3. Thus, for example, an exemplary embodiment may allow [in which] the positions of sleeve 24 as well as adjusting body 40 [may] to be varied by turning them by using suitable adjusting tools 56 and 52 [is possible].

The present invention is not limited to the exemplary embodiments presented here and it [is] may be suitable for any [designs] configuration of fuel injectors 1, e.g., for fuel injectors 1 [having] including piezoelectric or magnetostrictive actuators or outwardly opening fuel injectors 1.

[Abstract]

ABSTRACT OF THE DISCLOSURE

A fuel injector [(1)] for fuel injection systems of internal combustion engines, in particular for direct injection of fuel
5 into the combustion chamber of an engine, [having] including
an actuator [(10)], a valve needle [(3)] which is mechanically
linked to the actuator [(10)] and is acted upon by a restoring
spring [(23)] in a closing direction, for actuation of a valve
closing body [(4)], which together with a valve seat face
10 [(6)] forms a sealing seat, and [having] including a sleeve
[(24)] which pre-stresses the restoring spring [(23)]. An
adjusting body [(40)] is situated adjustably in the sleeve
[(24)] so that a fuel amount flowing through the fuel injector
[(1)] per unit of time is a function of the position of the
15 adjusting body [(40)] in the sleeve [(24)].

[(Figure 2)]